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(54) **Optical filter with improved crosstalk rejection**

Optischer Filter mit verbesserter Unterdrückung des Übersprechens

Filtre optique ayant une élimination des couplages parasites améliorée

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Description

Field of the Invention

[0001] This invention relates to optical integrated circuits (OICs) using wavelength division multiplexing (WDM), and more particularly to OICs having wavelength discriminating optical filters with improved crosstalk rejection.

Background of the Invention

[0002] Optical filters are essential components for demultiplexers in WDM optical networks. Recent developments in wavelength discriminating optical filters include filter networks based on multiple path interferometry. These devices use a plurality of substantially uncoupled connecting waveguides between planar multimoded coupling regions. The connecting waveguides and connected coupling regions are constructed on an OIC substrate.

[0003] One approach employs a phased array of waveguides connecting two free-propagation regions, and is termed an array waveguide grating filter (AWG). This device is described in U.S. Patents Nos. 5,002,350 and 5,136,671, issued March 26, 1991 and August 4, 1992 respectively.

[0004] Another approach uses multimode interference (MMI) coupling regions that are connected by guides to form a generalized Mach-Zehnder Interferometer. See for example, "Novel InP-based phased array wavelength demultiplexer using a generalized MMI-MZ configuration", C. Van Dam et al. Proceedings of the European Conference on Integrated Optics, Genoa, Italy, 2994, pp. 275-278.

[0005] As the number of channels in the WDM system is increased and/or wavelength spacing between channels is reduced, crosstalk becomes a dominant system issue. While phased waveguide array filters are remarkably effective even in devices with large channels (40 channel WDM devices for example) crosstalk is still a problem.

[0006] Sources of crosstalk usually fall into two categories. One is design of the device. There are physical limits to the amount of channel separation that can be geometrically accommodated for a given wafer (OIC) size, so there is a tradeoff between the size of the device and crosstalk tolerance. More difficult sources of crosstalk to address are those arising from material and processing variations. These can be abstruse and unpredictable. Nevertheless, the typical approach to the problem to date has been along these lines, i.e. developing new designs and improving process and material control. See for example, "The elimination of sidelobes in the arrayed waveguide WDM" by S. Day et al., presented at the Integrated Photonics Research Conference, April 29 May 2, 1996, Boston, MA., and reported in 1996 Technical Digest Series, Vol. 6, of the Optical Society of America, pp. 48 - 52, ISBN - 55752-438-6. While these efforts have met with some success, better solutions for the crosstalk problem in these devices is still sought. The reader is also referred to EP-A-0978 740 and US-A- 5748811 which are describing cascaded arranged waveguide gratings.

Statement of the Invention

[0007] I have developed an OIC approach to crosstalk rejection which deals directly with the problem by providing means in each output channel for filtering unwanted wavelengths. The invention consists in an optical integrated circuit (OIC) demultiplexer system as defined in the claims, using an AW or primary demultiplexer.

[0008] The device structure incorporates a second array of AWGs.

[0009] The second array functions as a clean up filter for the primary demultiplexer. The AWGs in the second array are smaller in size than in the first, but otherwise may be essentially identical. This commonality between the filter structures allows the same OIC processing to be employed for making both.

[0010] In an alternative embodiment, a MMI-MZ array is ganged with the primary demultiplexer for clean up filtering. In this case also, common processing steps may be used for fabricating the device.

Brief Description of the Drawing

[0011]

Fig. 1 is a schematic view of a demultiplexer device using an array of waveguides connecting two planar coupling regions;

Fig. 2 is a schematic view of one embodiment of the demultiplexer device of the invention;

Fig. 3 is a schematic view of a second embodiment of the demultiplexer device of the invention; and

Figs. 4-9 are schematic representations of process steps suitable for the manufacture of the devices of Figs. 2 and 3

Detailed Description

[0012] A conventional arrayed waveguide grating filter is shown in Fig. 1. This plan view shows the interior portion 11 of a planar OIC which contains an array of waveguides 14 connecting first,13, and second,15, planar coupling regions. A single input 12 is shown for the multiplexed signal. Additional input ports may be provided to allow a vernier selection of the position of the input signal for optimizing device performance. Where multiple input ports are provided, only one of the input ports for a given multiplexed signal is typically used.

[0013] The WDM input signal is coupled into waveguide 12 at the input end of OIC 11. The OIC interfaces, typically optical fiber pigtails, which for simplicity

are not shown in these figures, couple the multiplexed signal into the OIC at the input end, and couple the separated channels from the OIC output section to a plurality of fiber connections for distribution in the optical network. The WDM input signal enters coupler 13, and is distributed into portions which are coupled into the grating section 14. The grating section 14 comprises an array of waveguides of different linear lengths. The length of the individual waveguides in the array changes monotonically by a substantially equal amount across the array. This difference in the length of waveguides in the array results in a wavelength dependent tilt of the wave front of the lightwave in the grating section and shifts the input wave image to a wavelength dependent position. As the wavelength changes, the image of the input wave sweeps across and couples light into different output waveguides, i.e. 16-21.

[0014] The construction of the coupler elements follows conventional practice for star couplers. These devices are well known and suitable design techniques are well established in the art.

[0015] The number of grating waveguides is chosen so that they cover the far field distribution of the input waveguide ports of coupler 13. The number of grating waveguides is typically significantly greater, for example 3N, than the number N of output channels in the device to ensure relatively clean imaging of the input waves in the coupler slabs. The grating waveguides are closely spaced at the slab interfaces to minimize insertion loss. Power incident on the space between the waveguide ports is either lost, or may contribute optical noise as a result of reflections in the slab.

[0016] At the end of grating section 14 is another coupler 15 which functions as a mirror image of coupler 13 and separates the wave front in the coupler into six demultiplexed output signals 16-21. More details of the design and operation of waveguide star coupler regions is given by Yuan P. Li et al. in Chapter 8: Silicon Optical Bench Waveguide Technology, OPTICAL FIBER TELECOMMUNICATIONS, Vol. IIIB, pp. 319 et seq.

[0017] As mentioned above, device performance can be degraded by factors other than design limitations. For example, fluctuations in the index of refraction of the grating waveguides cause random phase errors in the grating and increase crosstalk. Also the precision of the device geometry design often cannot be realized due to variations in processing. Lithography generally determines spacing between waveguides, and can be accurately controlled. However, small errors in the absolute position of the waveguide elements, which have to be controlled over a relatively large wafer surface, can cause severe crosstalk problems. These errors have been addressed by providing more than one input port, as mentioned above, and selecting the input port that most effectively matches the output array ports to the system wavelengths required.

[0018] Despite careful efforts to control crosstalk in AWG type WDM demultiplexers, crosstalk levels in some devices, particularly those used in systems with a large number of channels, often exceed acceptable limits. An example is demonstrated by the following analysis. Based on addition of random binary crosstalk power to signal power, the induced power penalty may be derived from the crosstalk power by the expression:

$$P = - 10 \log (1-e) \qquad \text{Eq. 1}$$

where e is the crosstalk power and P is the power penalty measured
in dB. See, e.g., Chapter 5 of "Optical Networks" by R. Ramaswami and
K. N. Sivarajan, Morgan Kaufmann (1998). This indicates a power penalty
of 0.5 dB for a crosstalk power of - 10 dB, and a power penalty of 0.1 dB for a crosstalk power of - 16.4 dB. In practice, an incoherent crosstalk level of < -12 dB is often used as a standard for preventing significant system degradation. In advanced systems, a more stringent value may be imposed.

[0019] Taking a crosstalk target of -12 dB, for example, and allowing a typical 3 dB system margin, it is thus found that a demultiplexing filter that passes one channel amongst 32 in a 32 channel WDM system must provide a rejection level of at least 29.9 dB for unwanted crosstalk. In a 40 channel system, this rejection level rises to 30.9 dB, and to 34 dB in an 80 channel system. The rejection requirement is increased even further if there exists, or could exist, power divergence between different channels, as this would raise crosstalk power with respect to the power of the demultiplexed signal. For example, if power divergence is 7 dB, a 40 channel demultiplexer would require crosstalk rejection of 37.9 dB, and an 80 channel device would require a rejection level of 41 dB. Such rejection values are extremely hard to achieve in AWG devices using current state-of-the-art technology.

[0020] A typical system approach to provide this needed level of crosstalk rejection would be to modify the input of the channel at the channel station after distribution of the demultiplexed signals from the WDM. This would appear to be a simple and expedient solution. A suitable implementation would be to use discrete filter elements, which are bulk optical devices, pigtailed to each input at the station apparatus. The added cost of these devices, one for each WDM channel, and assembly of these devices at the receiver or the remote stations, is significant and for some applications, prohibitive.

[0021] The strategy used according to one embodiment of this invention is represented by Fig. 2. Here the OIC substrate carries the primary AWG demultiplexer, indicated generally at 32, and shown here with six output channels 33-38 for convenience in illustration. It will be recognized that this portion of the OIC is essentially that shown in Fig. 1. Each of the six output signals from de-

multiplexer 32 are routed by waveguides 33-38 into a secondary array of AWG devices 41-46. Devices 41-46 are identical in design concept to the AWG device 32. Each comprises an input coupler, a phased waveguide array, and an output coupler as shown. However, in contrast to the device 32, each of the devices 41-46 has a single output for each of the demultiplexed bands, and, as apparent, are substantially smaller. The devices 41-46 function as filters to clean up each of the demultiplexed bands and eliminate crosstalk. The power in the crosstalk that is eliminated by this secondary AWG array is discarded.

[0022] An alternative embodiment of the invention employs Mach-Zehnder filters for the secondary array. These devices also comprise multimode regions interconnected by waveguides of different optical path lengths. In this case the multimode regions are multimode interference couplers designed to provide images of the input signal to the entrance of the interconnecting guides. Wavelength filtering devices using MMI couplers in a generalized Mach-Zehnder arrangement are described in the C. Van Dam et al. reference cited earlier. Also see, "General self-imaging properties in N x M multimode interference couplers including phase relations," by M. Bachmann, P.S.A. Besse, and H. Melchior, Applied Optics, Vol. 33, pp 3905-3911, 1994; and "Design of phased array wavelength division multiplexers using multimode interference couplers, by M.R. Paiam and R.I. MacDonald, Applied Optics, Vol. 36, pp. 5097-5108, 1997.

[0023] The MMI-MZ provides a transmission function that is periodic in wavelength, repeating every free spectral range. Typically, the peak transmission is contained within a region of order 1/N to 1/2N of the free spectral range, where N is the number of arms (waveguides) in the MMI-MZ device.

[0024] An illustration of a demultiplexing device according to this aspect of the invention is shown in Fig. 3. The OIC substrate 61 contains the primary AWG demultiplexing stage 32, as before. The secondary channel filtering array comprises MMI-MZ devices 63-68 shown connected to the output of AWG demultiplexer 32 in a manner similar to that shown in Fig. 2. The six channel output, where the signal in each channel has been filtered of crosstalk, appears at 71-76 of the OIC.

[0025] It is recommended that the arrayed MMI-MZ filters 63-68 in the arrangement of Fig. 3, and the arrayed AWG filters 41-46 of Fig. 2, have pass bands that are significantly wider than the passband of the primary demultiplexer. This is to ensure that the secondary filter array does not introduce any loss of power in the main band of interest. It also allows for small process variations that could lead to a shift in the pass band away from the signal band.

[0026] Typically the number of waveguide arms interconnecting the MMI-MZ coupler regions is small in comparison with the number of waveguides in the grating array of the AWG devices described earlier, and the path length differences are not large. Accordingly, the secondary filter array of Fig. 3 is shown smaller than that in Fig. 2, and the size of the overall OIC maybe comparably reduced. Recalling that these figures are schematic, the actual size of the elements, and the actual size of the OICs may be significantly different than conveyed by the illustrations.

[0027] The MMI-MZ OIC embodiment is particularly useful when the overall system requirements are such that only a modest level of crosstalk rejection is required by the secondary filter array. This is due to the fact that the MMI-MZ arrays are, generally speaking, somewhat less efficient in filtering unwanted wavelengths in a signal. The lower filter efficiency is partly due to the typically small number of arms in the phased array section. So, the tradeoff between the devices of Figs. 2 and 3 will typically be filter performance vs. device size.

[0028] It will also be recognized that the OIC device of Fig. 3 and the OIC device of Fig. 2 share the common element of an array of waveguides where individual waveguides differ in length by predetermined amounts. This element is present in both the primary and the secondary arrays. Because of the relatively complex overall geometry of these arrays, they are ideally suited for a pure IC fabrication technique, wherein the layout complexity can easily be implemented using standard lithographic tools.

[0029] Optical integrated circuit fabrication techniques suitable for the manufacture of the devices described above may follow substantially known integrated circuit fabrication techniques. A example of a process sequence will be described in conjunction with Figs. 4-9, which figures represent steps in the fabrication sequence.

[0030] With reference to Fig. 4, which is essentially a view through section 4 - 4 of Fig. 3 , and is chosen mainly to illustrate the fabrication of the waveguide networks of the OICs of the invention, a silicon substrate 101 is shown with an oxide cladding layer 102 formed on the surface of the substrate. The preferred manufacturing method for these device is based on silicon optical bench (SOB) technology. Silicon is the preferred substrate choice largely for the well developed silicon technology, and the convenience of using doped SiO_2, a desirable waveguide material. Other materials can be used, based on materials such as InP, GaAs, fused silica, et al., even polymer materials.

[0031] The substrate 101 in Fig. 4 may be a portion of a larger wafer which is singulated after wafer fabrication is complete into several or many demultiplexer devices. The actual size of the optical integrated circuit for a typical AWG (primary demultiplexer)/AWG (secondary array) or an AWG/MMI-MZ device may be as small as 50 mm^2 for a device used for demultiplexing only a few channels, up to, for example, 50 cm^2 for a device built for many channels. Large devices, such as the latter, may consume an entire 5" wafer, and processing and packaging of single devices entirely at the wafer level is

a likely manufacturing approach.

[0032] The lower cladding layer, or base layer, 102 is typically undoped silica, grown by steam oxidation or deposited by low pressure chemical vapor deposition (LPCVD). Other techniques for making thick SiO_2 layers, such as flame hydrolysis (FHD or VAD), also can be used. The thickness of the lower cladding layer is typically 10-50 microns.

[0033] The thick SiO_2 layers are typically consolidated by annealing, as is known in the art. Layers produced by so-called "soot" techniques, e.g. FHD, must be consolidated. Layers produced by e-beam techniques may be useful as deposited.

[0034] With reference to Fig. 5, a waveguide core layer 103 is deposited on the lower cladding layer 102. The essential property of core layer 103 is a refractive index that is slightly higher than that of the lower cladding layer. Typically this is obtained by doping the core layer. A traditional dopant in the CVD process has been phosphorus, which may produce a refractive index difference, Δ, between the doped core and the undoped cladding of 0.4-0.8%, and is suitable for the devices described here. Alternatively, higher Δ values may be provided using Ge doping, which allows waveguides with smaller bend radii to be used without detrimental radiation losses, thus providing more compact device structures. Other deposition processes and other dopant and dopant combinations are possible. The thickness of the core layer 103 corresponds to the waveguide dimension. The waveguides are typically approximately square in shape, to accommodate essentially circular propagating modes. The width and thickness of the waveguides are typically in the range 2-10 μm.

[0035] As shown in Fig. 6, the waveguide layer 103 is masked with a photolithographic mask having features 104, corresponding to the six waveguides appearing in Fig. 3. The mask is preferably a tri-level photoresist. Alternatively a hard mask of, e.g. chrome or silicon, may be used. The wafer is then etched using dry etching, preferably reactive ion etching (RIE), to define the waveguides as shown in Fig. 7. Other suitable etching techniques such as chemically assisted ion beam etching (CAIBE) or inductively coupled plasma reactive ion etching (ICP-RIE) may be used. Dry etching is preferred because it forms relatively vertical sidewalls for the waveguides. The photomask is then removed leaving the structure of Fig. 8, with individual waveguides shown at 105. The slight over etch shown in the figures is to ensure complete optical isolation between the waveguides. Since the dimensions involved are relatively large, control of the etch to the desired end point is straightforward.

[0036] Referring to Fig. 9, the waveguides 105 are overcoated with upper cladding layer 107. This layer may be undoped silica, the same as the lower cladding layer 102. However it is important to completely fill the spaces between the waveguides. To ensure this, a doped silica upper layer may be used, which can be reflowed at moderate annealing temperatures to eliminate voids in the structure. The upper cladding layer 107 may have a thickness in the range 5-50 microns. The preferred approach to producing thick SiO_2 layers is to deposit them in more than one step, with annealing steps intervening.

[0037] It is evident that the processing required for the secondary filter array of the invention is essentially identical to that required to form the primary wavelength division demultiplexer. The only significant modification in the manufacturing process is the configuration of the mask set used in the lithography steps. Thus a major improvement in device performance is obtainable with a minimum of process modification.

[0038] A demultiplexer device according to the invention was constructed using 0.9% index contrast doped silica waveguides. The demultiplexer was designed for a 100 GHz 16 channel WDM system operating around a nominal wavelength of 1.55 μm. The primary demutliplexer AWG provided approximately 35-40 dB of crosstalk suppression. The secondary AWGs, monolithically integrated with the first, provided approximately 30-35 dB of additional crosstalk suppression. The combined demultiplexer/filter of the invention provided enhanced crosstalk suppression of approximately 65-75 dB. The passband of the secondary AWG filters was more than twice that of the primary AWG demutliplxer.

[0039] For the purpose of definition here, and in the appended claims, the term "waveguide array" is intended to define an array of from 4-100 optical waveguides with each waveguide in the array having a unique length that differs from the other waveguides in the array by a predetermined amount. The term "uniform phased waveguide array" is intended to define an array of from 4-100 optical waveguides all extending substantially parallel, with each waveguide in the array, in ascending order, having a length that differs by a substantially constant amount from its ascending neighbor.

[0040] Various additional embodiments of this invention will occur to those skilled in the art. All deviations from the specific teachings of this specification that fall within the claims are considered within the scope of the invention.

Claims

1. An optical integrated circuit, hereinafter referred to as OIC, demultiplexer system comprising:

a. a substrate (11),
b. an OIC demultiplexer system input waveguide on the substrate (12).
c. a demultiplexer (14, 32) optically coupled to the OIC input waveguide, the demultiplexer comprising:

i. an input multimode region (13),

ii. an output multimode region (15), the output multimode region having a plurality of N output waveguides (33-38), and
iii a waveguide array (14) optically coupling the input multimode region to the output multimode region.

d. a plurality of N wavelength filters, each of the plurality N of filters optically coupled to one of the plurality N of output waveguides, each of the plurality N of filters comprising:

iv. an input multimode region,

v. an output multimode region,

vi. a waveguide array (41-46) optically coupling the input multimode region to the output multimode region, and

e. a respective single output waveguide (51-56) optically coupled to each of the N filters, the OIC demultiplexer system being **characterized in that** the optical paths:

between the OIC demultiplexer system input waveguide and the demultiplexer,
between the demultiplexer and the plurality N of filter, and
between the plurality N of filters and the single demultiplexer system output waveguide optically coupled to each of the filters, each consist of a respective single waveguide, and the OIC being further **characterized in that** the waveguide arrays of the filters have a passband wider than the passband of the waveguide array of the demultiplexer.

2. The OIC of claim 1, wherein the plurality N of filters are Multimode Interferometer Mach-Zehnder filters.

3. The OIC of claim 1, wherein the substrate is silicon and the waveguide comprises SiO_2.

4. The OIC of claim 1, wherein N is greater than 10.

5. The OIC of claim 1, wherein the input waveguide is designed to transmit an input signal comprising at least four channels, and means for coupling the input signal to the OIC input waveguide are provided.

6. The OIC of claim 1, wherein said single output waveguide carries a single channel.

7. The OIC of claim 2, wherein each of the plurality of N of output waveguides from the demultiplexer carries a single channel.

8. The OIC of claim 2, wherein the input waveguide is designed to transmit an input signal comprising at least four channels, and means for coupling the input signal to the OIC input waveguide are provided.

9. The OIC of claim 8, wherein said single output waveguide carries a single channel.

10. The OIC of claim 9, wherein each of the plurality N of output waveguides from the demultiplexer carries a single channel.

Patentansprüche

1. Optisches, integriertes, Schaltkreis, im folgenden als OIC bezeichnet, Demultiplexer-System, umfassend:

a. ein Substrat (11),

b. ein OIC-Demultiplexer-System-Eingangs-Wellenleiter auf dem Substrat (12),

c. einen Demultiplexer (14,32), der optisch mit dem OIC-Eingangs-Wellenleiter gekoppelt ist, wobei der Demultiplexer umfaßt:

i. eine Eingangs-Mehrfachmoden-Region (13),

ii. eine Ausgangs-Mehrfachmoden-Region (15), wobei die Ausgangs-Mehrfachmoden-Region eine Mehrzahl von N Ausgangs-Wellenleitern (33-38) aufweist, und

iii. ein Wellenleiter-Array (14), das optisch die Eingangs-Mehrfachmoden-Region mit der Ausgangs-Mehrfachmoden-Region koppelt.

d. eine Mehrzahl von N Wellenlängen-Filtern, wobei jeder der Mehrzahl N der Filter optisch mit einem der Mehrzahl N der Ausgangs-Wellenleiter gekoppelt ist, wobei jeder der Mehrzahl N der Filter umfaßt:

iv. eine Eingangs-Mehrfachmoden-Region,

v. eine Ausgangs-Mehrfachmoden-Region,

vi. ein Wellenleiter-Array (41-46), das optisch die Eingangs-Mehrfachmoden-Region mit der Ausgangs-Mehrfachmoden-Region koppelt und

e. einen Einzel-Ausgangs-Wellenleiter (51-56), der optisch mit der N Filter gekoppelt ist, wobei das OIC-Demultiplexer-System **dadurch gekennzeichnet ist, daß** die optischen Pfade:

zwischen dem OIC-Demultiplexer-System-Eingangs-Wellenleiter und dem Demultiplexer,

zwischen dem Demultiplexer und der Vielzahl N der Filter, und

zwischen der Vielzahl N der Filter und dem Einzel-Demultiplexer-System-Ausgangs-Wellenleiter, der optisch mit jedem Filter verbunden ist,

aus einem Einzel-Wellenleiter bestehen und der OIC ist weiter **dadurch gekennzeichnet, daß** die Wellenleiter-Arrays der Filter einen Durchlaßbereich aufweisen, der weiter als der Durchlaßbereich des Wellenleiter-Arrays des Demultiplexers ist.

2. OIC nach Anspruch 1, wobei die Mehrzahl N der Filter Mehrfachmoden-Interferometer Mach-Zehnder-Filter sind.

3. OIC nach Anspruch 1, wobei das Substrat Silicium ist und der Wellenleiter SiO_2 enthält.

4. OIC nach Anspruch 1, wobei N größer als 10 ist.

5. OIC nach Anspruch 1, wobei der Eingangs-Wellenleiter ausgebildet ist, um ein wenigstens vier Kanäle umfassendes Eingangs-Signal zu übertragen, und Mittel zum Koppeln des Eingangs-Signals zu dem OIC-Eingangs-Wellenleiter vorgesehen sind.

6. OIC nach Anspruch 1, wobei der Einzelausgangs-Wellenleiter auf einen Einzelkanal überträgt.

7. OIC nach Anspruch 2, wobei jeder der Vielzahl N der Ausgangs-Wellenleiter abgehend vom Demultiplexer auf einen Einzelkanal überträgt.

8. OIC nach Anspruch 2, wobei der Eingangs-Wellenleiter ausgebildet ist, um ein wenigstens vier Kanäle aufweisendes Eingangs-Signal zu übertragen, und Mittel zum Verbinden des Eingangs-Signals des OIC-Eingangs-Wellenleiters vorgesehen sind.

9. OIC nach Anspruch 8, wobei der Einzelausgangs-Wellenleiter auf einen Einzelkanal überträgt.

10. OIC nach Anspruch 9, wobei jeder der Vielzahl N der Ausgangs-Wellenleiter abgehend vom Demultiplexer auf einen Einzelkanal überträgt.

Revendications

1. Système démultiplexeur à circuit optique intégré, désigné ci-après sous le nom de OIC, comprenant :

a. un substrat (11),
b. un guide d'ondes d'entrée du système démultiplexeur à OIC sur le substrat (12),
c. un démultiplexeur (14, 32) optiquement couplé au guide d'ondes d'entrée du OIC, le démultiplexeur comprenant :

i. une région multimode d'entrée (13),
ii. une région multimode de sortie (15), la région multimode de sortie comportant une pluralité de N guides d'ondes de sortie (33 à 38), et
iii. un réseau de guides d'ondes (14) couplant optiquement la région multimode d'entrée à la région multimode de sortie.

d. une pluralité de N filtres de longueurs d'ondes, chacune des pluralités N des filtres étant optiquement couplée à l'une des pluralités N de guides d'ondes de sortie, chacune des pluralités N des filtres de N comprenant :

iv. une région multimode d'entrée,
v. une région multimode de sortie,
vi. un réseau de guides d'ondes (41 à 46) couplant optiquement la région multimode d'entrée à la région multimode de sortie, et

e. un guide d'ondes de sortie unique respectif (51 à 56) optiquement couplé à chacun des N filtres, le système démultiplexeur à OIC étant **caractérisé en ce que** les chemins optiques :

entre le guide d'ondes d'entrée du système démultiplexeur à OIC et le démultiplexeur, entre le démultiplexeur et la pluralité N de filtres, et
entre la pluralité N de filtres et le guide d'ondes de sortie du système démultiplexeur unique optiquement couplé à chacun des filtres,

chacun consistant en un guide d'ondes unique respectif, et l'OIC étant en outre **caractérisé en ce que** les réseaux des guides d'ondes des filtres comportent une bande passante plus large que la bande passante du réseau de guides d'ondes du démultiplexeur.

2. OIC selon la revendication 1, dans lequel la pluralité N des filtres sont des filtres d'interféromètre multimode Mach-Zehnder.

3. OIC selon la revendication 1, dans lequel le substrat est du silicium et le guide d'ondes comprend du SiO_2.

4. OIC selon la revendication 1, dans lequel N est supérieur à 10.

5. OIC selon la revendication 1, dans lequel le guide d'ondes d'entrée est conçu pour émettre un signal d'entrée comprenant au moins quatre canaux, et des moyens pour coupler le signal d'entrée au guide d'ondes d'entrée du OIC sont fournis.

6. OIC selon la revendication 1, dans lequel ledit guide d'ondes de sortie unique porte un canal unique.

7. OIC selon la revendication 2, dans lequel chacune des pluralités N de guides d'ondes de sortie à partir du démultiplexeur porte un canal unique.

8. OIC selon la revendication 2, dans lequel le guide d'ondes d'entrée est conçu pour émettre un signal d'entrée comprenant au moins quatre canaux, et des moyens pour coupler le signal d'entrée au guide d'ondes d'entrée du OIC sont fournis.

9. OIC selon la revendication 8, dans lequel ledit guide d'ondes de sortie unique porte un canal unique.

10. OIC selon la revendication 9, dans lequel chacune des pluralités N des guides d'ondes de sortie à partir du démultiplexeur porte un canal unique.

FIG. 1

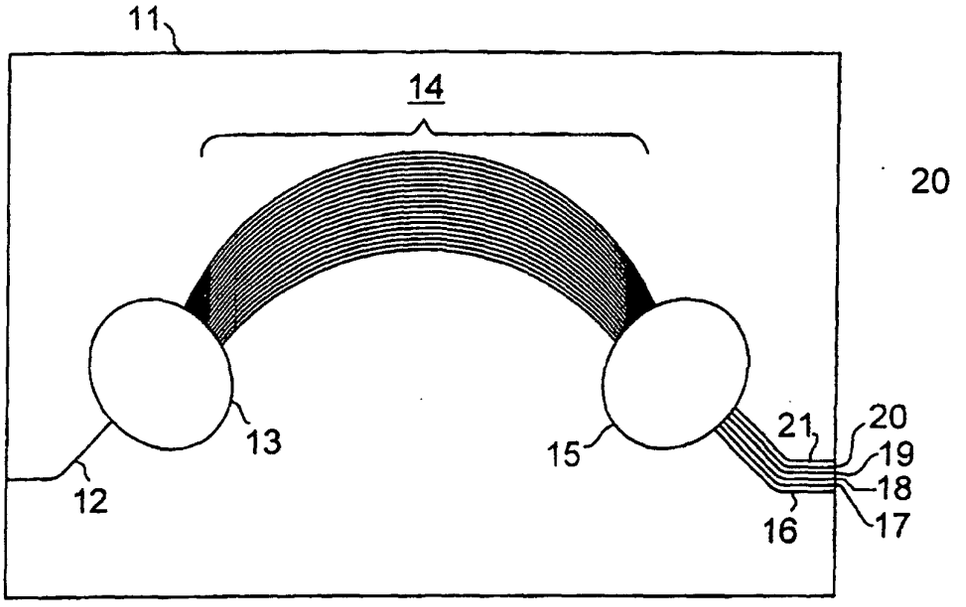

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FIG. 2

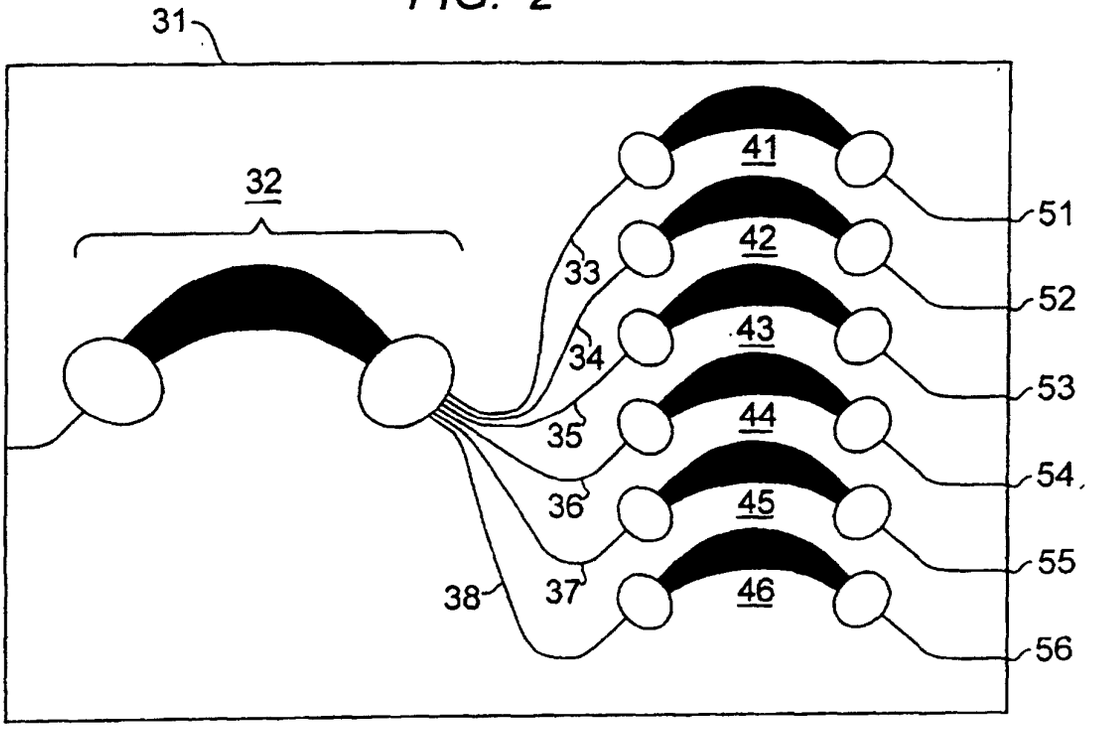

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FIG. 3

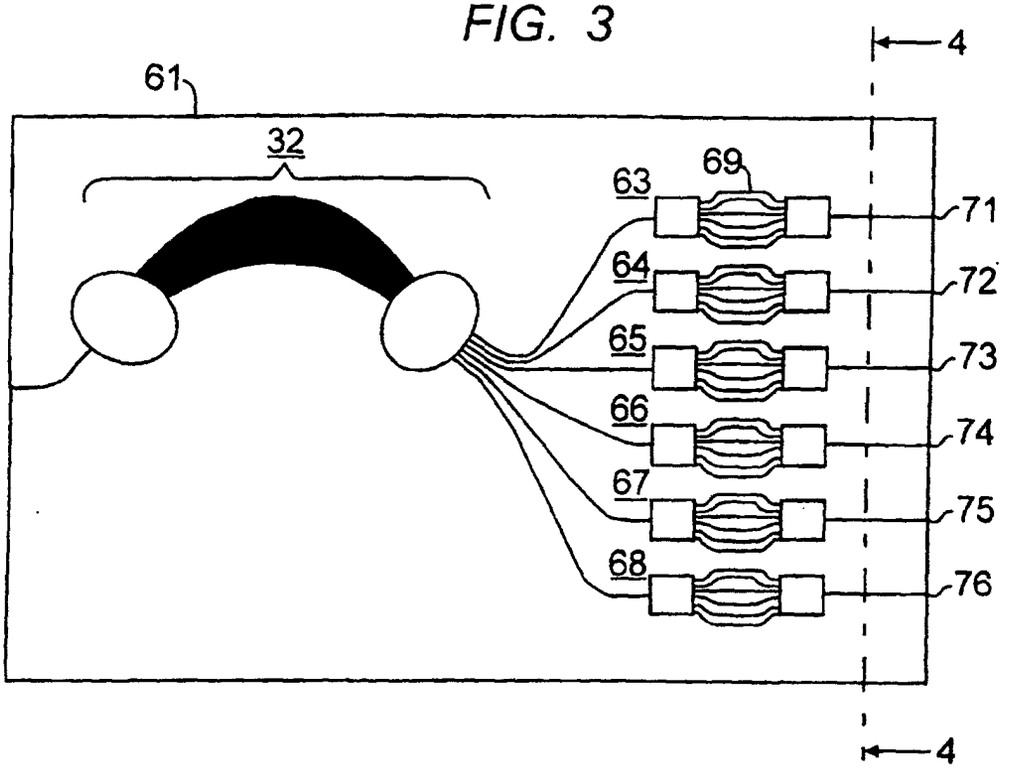


FIG. 4

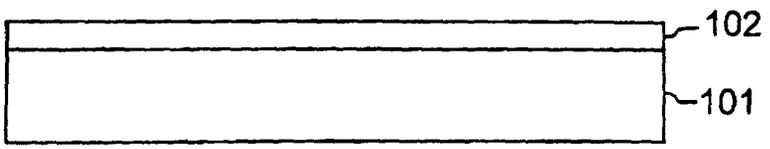


FIG. 5

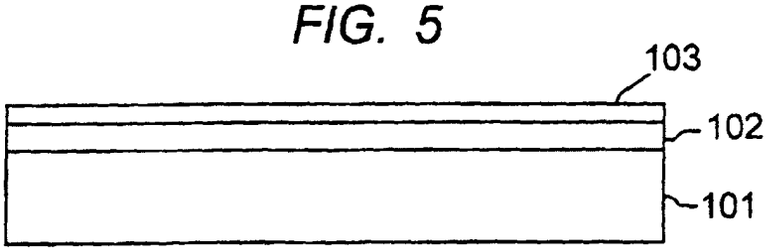


FIG. 6

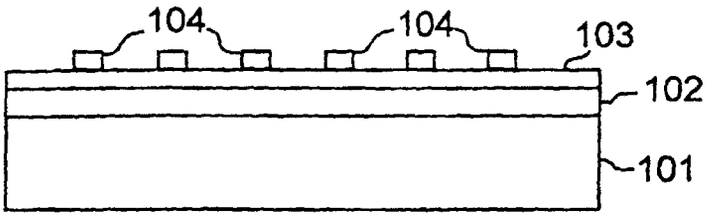


FIG. 7

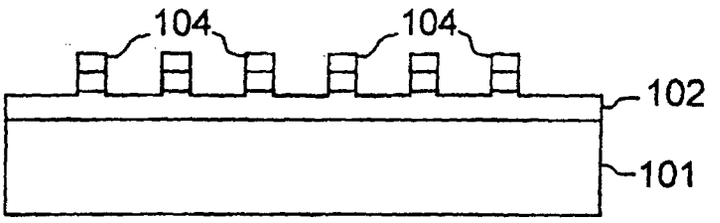


FIG. 8

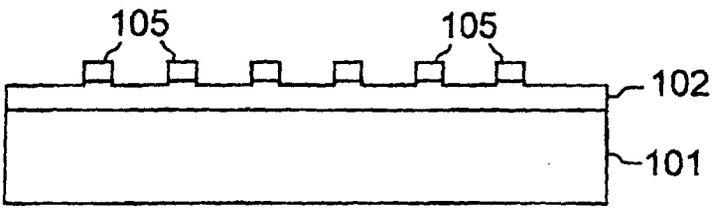


FIG. 9

